Bridge Street Bridge
Spans Grand River, links
Michigan Street and Bridge Street
Grand Rapids
Kent County
Michigan

HAER No. MI-27

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD
MID-ATLANTIC REGION, NATIONAL PARK SERVICE
DEPARTMENT OF THE INTERIOR
PHILADELPHIA, PENNSYLVANIA 19106

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HISTORIC AMERICAN ENGINEERING RECORD

BRIDGE STREET BRIDGE

HAER No. MI-27

Location: The bridge spans the Grand River in downtown Grand Rapids, Kent County, Michigan and links Michigan Street on the east and Bridge Street on the west.

UTM: 16.608085.4758170
Quad: Grand Rapids, West - Michigan

Date of Construction: 1903-1904, Railing replaced 1959.

Present Owner: City of Grand Rapids
300 Monroe Avenue, N.W.
Grand Rapids, MI 49503

Present Use: Vehicular/Pedestrian Bridge.

Significance: The Bridge Street Bridge is a rare early example of a reinforced concrete arch, earth-filled bridge, and one of great size, measuring 468 feet long overall. This bridge is the second largest known surviving example of this design in Michigan. This was one of the earliest large reinforced concrete arch, earth-filled bridges built in the United States and received considerable attention in the national engineering literature. It was listed as eligible for the National Register of Historic Places in April, 1986.

Project Information: This documentation was undertaken in December, 1987 in accordance with the memorandum of Agreement by the City of Grand Rapids, Federal Highway Administration, State Historic Preservation Office and the Michigan Department of Transportation as a mitigative measure prior to demolition and replacement of the bridge in early 1988.

Robert Phillips
Environmental Scientist
Williams and Works
Grand Rapids, Michigan

The existing Bridge Street Bridge is located in downtown Grand Rapids, Michigan as shown in the general location map. The bridge and its immediate surroundings are shown on the Bridge Street Bridge site map. The bridge connects Michigan Street on the east and Bridge Street on the west.

The existing bridge is the fifth bridge to be built at this location. The first was a wooden foot bridge built in circa 1842 (7). A second bridge was built at this location in 1852 by the Grand Rapids Bridge Company (7). This toll bridge, burned in 1858 and was rebuilt that same year (7). This structure was replaced with the fourth bridge at this location in 1884 (7). Since the construction of this first bridge, this crossing location of the Grand River has been an important link between the downtown central business area and the west side residential and commercial areas. As such the crossing has always been important and vital to the economic health of the city as well as the convenience for commerce and pedestrian traffic (6).

An historical photograph (MI-27-16) indicates that a steel tressel type rail bridge was located at this crossing just prior to the construction of the present reinforced concrete arch, earth-filled bridge. In fact, the photograph and published reports reveal that the old tressel bridge was used as a construction way and integal part of the new structure (9).

In circa 1902, the city decided to replace the steel tressel bridge with a new reinforced concrete arch, earth-filled bridge over the Grand River at Bridge Street. The new bridge to be designed/build under the supervision of L.W. Anderson, City Engineer for Grand Rapids, was to be designed to carry pedestrian and train traffic (9). The bridge which carried two sets of tracks, was built by Joseph P. Rusche, contractor of Grand Rapids for a cost of $87,400 (9)(1). The construction of the bridge began on the substructure with the excavation of the two new piers and abutments in June 17, 1903. Both piers and abutments were completed to the spring line level by November 24, 1903. The bridge construction was completed in late 1904 (9). A bronze plaque, which is no longer present on the bridge, was fashioned and affixed to the bridge to commenerate the completion of the construction of the bridge. This plaque, acknowledges the Mayor of Grand Rapids, Mr. Sweet, Board of Public Works President, Mr. Rowson, the City Engineer, Mr. Anderson, the builder Mr. Rusche and the1903-1904 erection date (Photocopy of original design drawing, MI-27-18).

The Bridge Street Bridge is a rare example of a reinforced concrete arch, earth-filled bridge and is one of great size. The bridge is the second largest known surviving example of this design in Michigan. This was one of the earliest large reinforced concrete arch, earth-filled bridges in the United States and received considerable attention in the national engineering literature (9). Based upon these facts and the overall importance of the bridge to the economy and transportation linkage to the community of Grand Rapids, the Bridge Street Bridge was determined to be eligible for the National Register of Historic Places by the State Historic Preservation Office and the National Park Service in April 1986.

The history of the Bridge Street Bridge is largely limited to those facts that can be gleaned from a few original drawings prepared by the City Engineer, several historic photographs and a number of newspaper articles (2)(3)(4)(8). Unfortunately, the City plans are incomplete and the presence or existance of the building contractor's shop drawings are unknown. The best single source concerning the construction of the bridge was an article presented in the Engineering News, published in New York in December 1904 (9).

The Bridge Street Bridge is a five span, reinforced concrete arch, earth-filled bridge (Photocopy of plans for Bridge Street Bridge across Grand River at Grand Rapids, Michigan, April 17, 1903, Plan 2 - sheets 1 and 2). The existing bridge is 468 feet long and 64 feet wide with a deck area of 29,952 square feet. The structure consists of five unequal spans or arches with the four piers and abutments founded in bedrock (Photocopy of Plan 2 - sheets 1 and 2) (Photocopy of plans for retaining walls on Bridge Street between Grand River and West Canal, 1903)(9). The center span is 87 feet long, the two spans abutting the center span are 83 feet long, while the two spans abutting the river banks are 79 feet in length (Photocopy of Plan 2 - sheets 1 and 2)(Photocopy of Contract No. 210, sheets 1 and 3, plans of centering for 79 foot and 87 foot spans, concrete steel bridge over Grand River at Bridge Street, Grand Rapids, Michigan, Feb. 25, 1904)(9). The substructure and arch ring construction technique is discussed in some detail in the Engineering News article (9). Following the completion of the arch rings, the spandral walls were constructed. Cross sections of the spandral walls are shown on the City drawings (Photocopy of Plan 2 - sheets 1 and 2) and in the Engineering News article (9) and require no further mention here.

Once the spandral and parapet walls were completed, the structure was filled with earth fill from local sources. The fill was placed to a height that would allow a 12 inch pavement or wearing surface including sidewalks and rail trackage to be constructed (9). The wearing surface of the original bridge was most likely concrete and brick as indicated by a City drawing of an adjacent section of roadway (Photocopy of plan for walls and superstructure to complete Grand Trunk subway at East Bridge Street, circa 1903).

The approaches to the abutments were made boxed shape and of concrete reinforced by Johnson bars (Photocopy of plans for retaining walls on Bridge Street between Grand River and West Canal, 1903)(Photocopy of plan for ducts, sidewalks and retaining wall on Bridge Street from Grand River to the West Canal, 1903)(2). The City's drawings also detail an underground passage at the east end of Bridge Street Bridge (Photocopy of plan for underground passage at east end of Bridge Street Bridge, June 17, 1904).

The bridge was not overly ornate and presented a simple appearance. The railing details and ornamental design applied to the bridge are shown in the City plans (Photocopy of Plan 2, sheets 1 and 2) and as aptly described in the Engineering News article (9). The railings and ornamental parts of the bridge such as keystones, brackets, consoles, dentiles and panels were cast in molds and set in place much as cut stone would be.

The bridge has 8-feet wide sidewalks on each side of the deck. The original railing, replaced in 1959, consisted of concrete parts and steel lattice railings (5). Over time, the bridge has had many different wearing surfaces from bricks to asphalt. The present wearing surface is asphalt with the sidewalks composed of concrete.

A documentation search did not identify any references to significant historical or note worthy events associated with the Bridge Street Bridge. The existing bridge continues to play an important role in the local community. Of the seven bridges that cross the Grand River in this area, the Bridge Street Bridge is the most centrally located and carries the most traffic (6). This bridge is an important link and is vital to the economic health of the City, as well as the convenience of residents. The bridge is also very important to police and fire protection and for public transportation.

The bridge, including its ornamentation is presently deteriorated to the point where replacement is justified and has been authorized to commence in early 1988.

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2. "Broken Brace Upsetting to Crane Operator." The Grand Rapids Press, October 31, 1974, p. A-1. (Original article in possession of Grand Rapids City Library, Michigan Room).

3. "City Bridges Bear Scars of Time." The Grand Rapids Press, October 4, 1964, p. A-10. (Original article in possession of Grand Rapids City Library, Michigan Room).

4. "City Bridges Conquer the Meandering Grand." The Grand Rapids Press, July 26, 1959, magazine section, p. 18. (Original article in possession of Grand Rapids City Library, Michigan Room).

5. City of Grand Rapids, Department of Public Services, Division of Engineering. 1959. Project No. 59-1013. Proposed Railing for Bridge Street Bridge. Approved June 24, 1959. Revised July 10, 1959. (Original Drawings in possession of City Engineer's Office, Grand Rapids, Michigan).

6. City of Grand Rapids. 1987. Environmental Assessment and Programmatic Section 4(f) Evaluation, Bridge Street Bridge, City of Grand Rapids, Kent County, Michigan. September 11, 1987. (Copy of assessment in possession of City Engineer's Office, Grand Rapids, Michigan).

7. The Grand Rapids Press, January 25, 1987, Wonderland Magazine, p. 5. (Original article in possession of Grand Rapids City Library, Michigan Room).

8. "Ravages of Time." The Grand Rapids Press, October 3, 1974, p. B-2. (Original article in possession of Grand Rapids City Library, Michigan Room).

9. Tubesing, Wm. F. 1904. "Structural Details of the New Reinforced Concrete Bridge at Grand Rapids, Michigan." MSIAS; Engineering News 52(20);489.

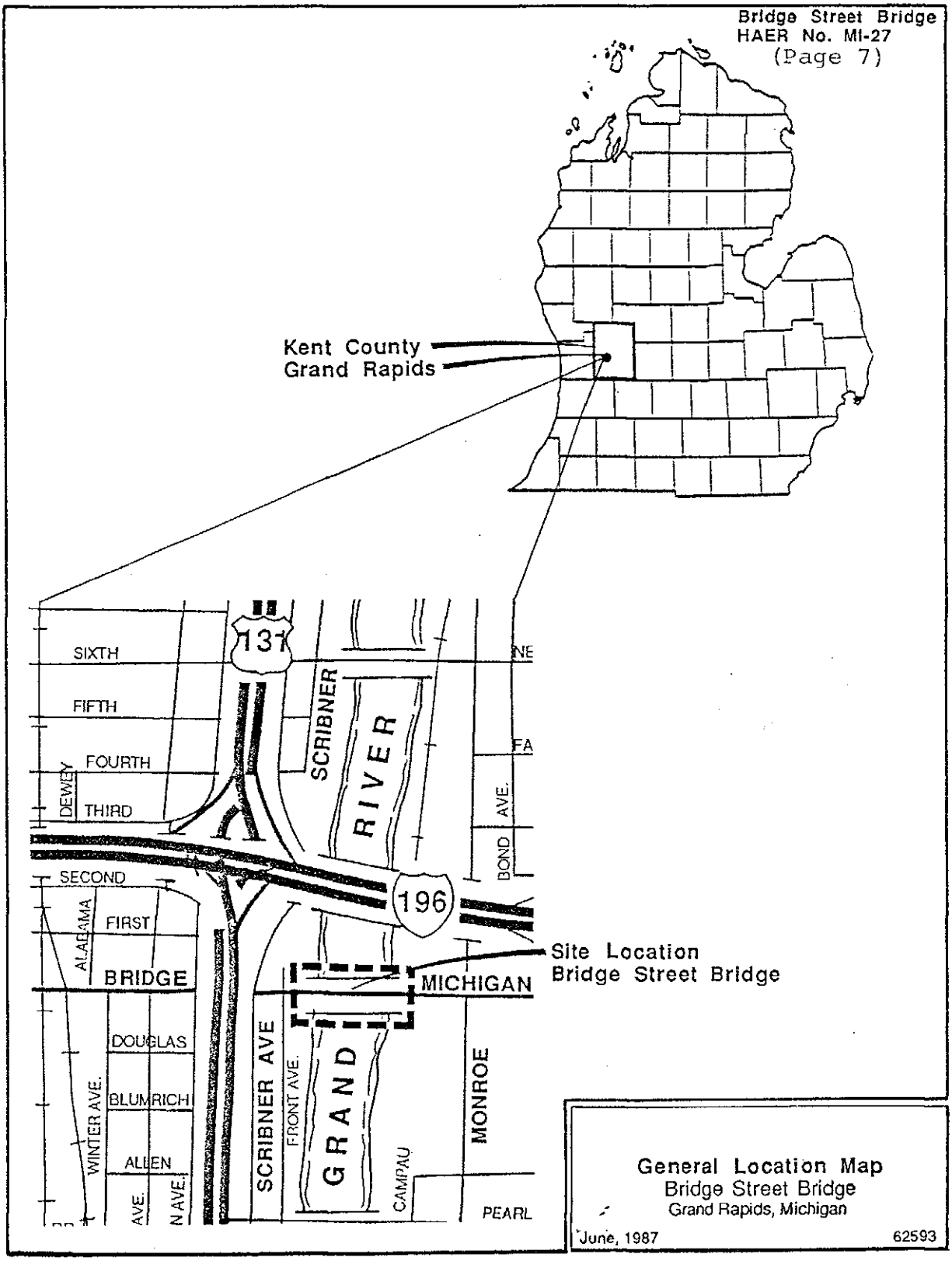
GRAPHIC DOCUMENTATION

1. General Location Map, Bridge Street Bridge, Grand Rapids, Michigan.

2. Bridge Street Bridge Site Map, Grand Rapids, Michigan.

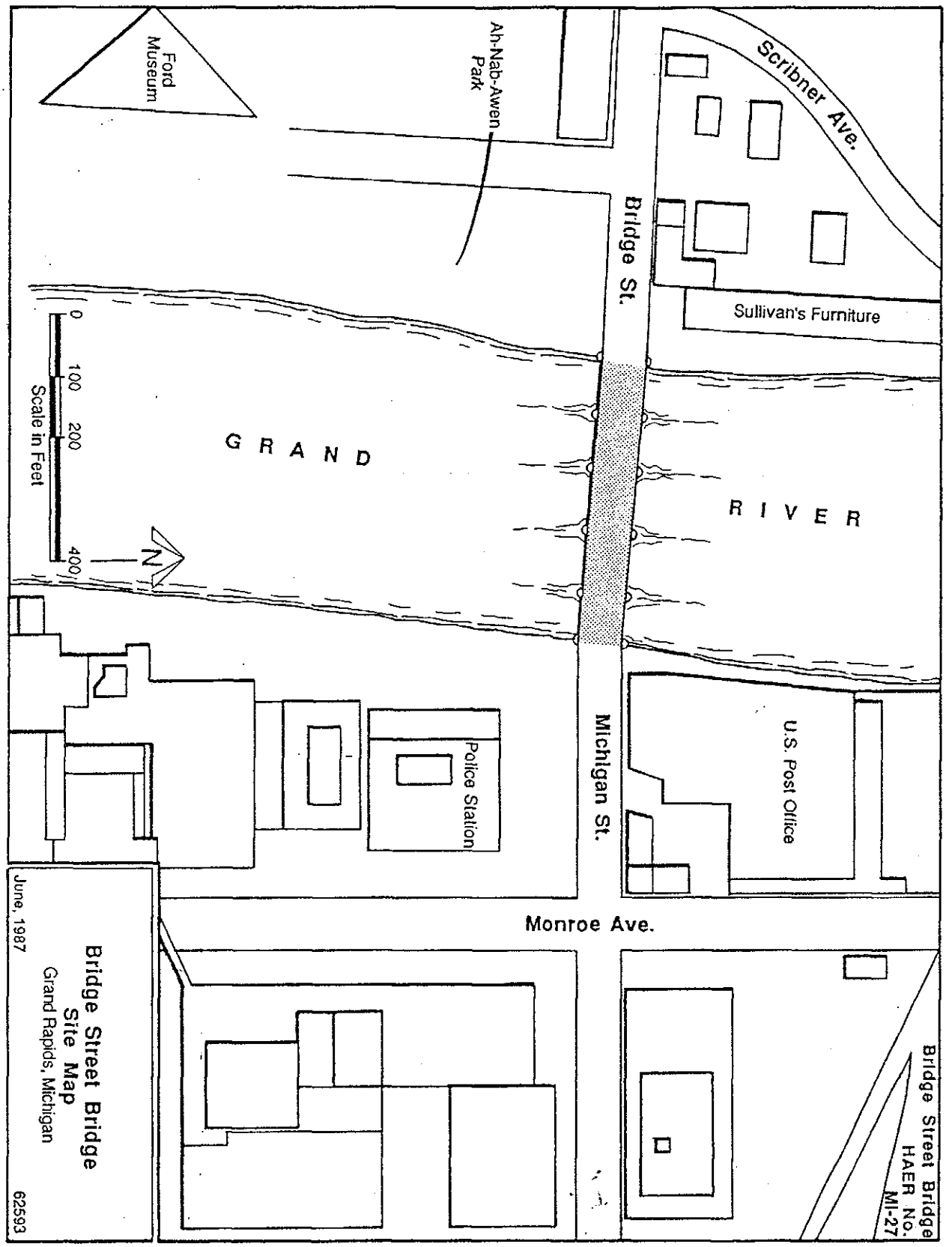
3. Tubesing, Wm. F. 1904. "Structural Details of the New Reinforced Bridge at Grand Rapids, Michigan." (Photocopy). Engineering News 52(20):489.

Note: 8" x 10" archivally stable negatives and contact prints of original drawings are itemized in Index To Photographs i.e. MI-27-18 through MI-27-25.



General Location Map
Bridge Street Bridge
Grand Rapids, Michigan

June, 1987 62593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R I V E R
Police Station
Michigan St.
U.S. Post Office
Monroe Ave.
Bridge Street Bridge
Site Map
Grand Rapids, Michigan
June, 1987
62593
Bridge Street Bridge
HAER No.
MI-27

ENGINEERING NEWS

A JOURNAL OF CIVIL, MECHANICAL, MINING AND ELECTRICAL ENGINEERING

Vol. LII. No. 22. New York, December 1, 1904.

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STRUCTURAL DETAILS OF THE NEW REINFORCED CONCRETE BRIDGE AT GRAND RAPIDS, MICH.

By Wm. F. Tubesing.*

GENERAL DESCRIPTION.—There has recently been completed across the Grand River at Grand Rapids, Mich., a new street bridge of reinforced concrete which deserves to be classed as a model structure of its kind. This bridge was designed and built under the direction of Mr. L. W. Anderson, City Engineer, and it consists of five arch spans, one 57 ft., two 63 ft. and two 79 ft. long. Fig. 1 shows an elevation and longitudinal section of one of the arch spans, and Fig. 2 shows details of the spandrel and parapet wall construction and of the railings. The main dimensions and general structural features of the bridge can be determined quite clearly from these drawings.

LOADS AND CONDITIONS.—The loading and other conditions assumed in designing the bridge were as follows:

Dead load.	Lbs. per cu. ft.
Concrete	150
Earth filling	120
Pavement, 12 ins. deep	150
Live load.	**Lbs. per sq. ft.**
Center, 20 ins. of roadway	250
Remainder of roadway	150
Sidewalks	100

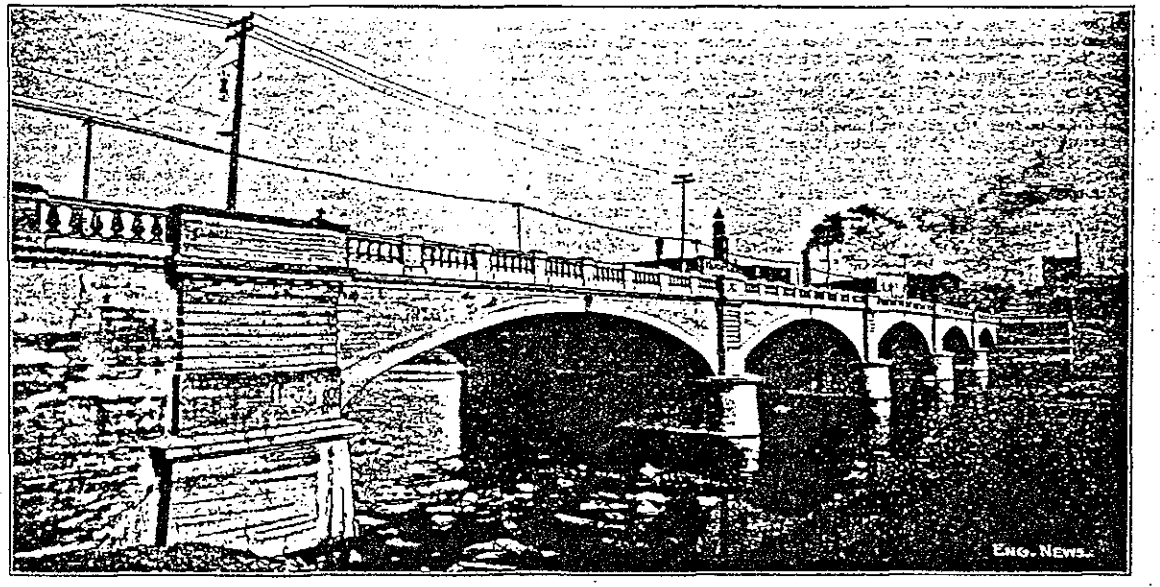
For concentrated load on the roadway the designer assumed a 15-ton steam road roller 11 ft. between axles, with 6 tons on the forward wheel 4 ft. wide and 4½ tons on each of the two rear wheels 20 ins. wide and 5 ft. apart on centers. The assumed moduli of elasticity were 1,500,000 for concrete and 30,000,000 for steel. The maximum compression allowed on the concrete in the arches was, excluding temperature stresses, 500 lbs. per sq. in., and, including temperature stresses due to a variation of 40°, 75 lbs. per sq. in. The maximum tension allowed in the concrete in the arches was, including temperature stresses due to a variation of 40°, 75 lbs. per sq. in., and, excluding temperature stresses, 50 lbs. per sq. in. The maximum shear allowed was 75 lbs. per sq. in. Concrete slabs, girders, beams, floors, walls and posts were required to have a safety factor of 4 in one month.

It was required that steel ribs under a stress not exceeding 18,000 lbs. per sq. in. must be able to take the entire bending moment of the arch without aid from the concrete and have flange areas of not less than the 1-50th part of the total of the arch and 1-50th of the crown. The actual stress in the steel, when embedded in and acting in combination with the concrete, was required not to exceed 20 times the allowable stress in the concrete. In slabs, girders, beams, floors and walls subjected to transverse stress, the steel was assumed to take the entire stress without aid from the concrete. The imbedded steel in walls and posts subjected to compression only was used as a precaution against cracks due to shrinkage.

SUBSTRUCTURE.—The substructure of the bridge consists of four piers and two abutments of the general construction shown by Fig. 1. Both piers and abutments rest upon a rock bottom of limestone; to get to solid rock excavation had to be carried through hardpan containing granite boulders. Work on the excavation for the piers was begun June 17, 1903, and both piers and abutments were completed to the springing line level on Nov. 24, 1903. There were about 2,000 cu. yds. of excavation, and 4,000 cu. yds. of concrete work involved. The approaches to the abutments were made box-shaped, of concrete, reinforced by Johnson bars. The space between the west approach walls was filled with stone and gravel, and that between the east approach walls was utilized for a public comfort station.

Two grades of concrete were used for the abutments. For the lower portion of the abutments the concrete consists of 1 part natural cement, 2½ parts sand and 4 parts gravel, and for the upper portion the concrete is composed of 1 part Portland cement, 3½ parts sand and 7 parts gravel. The last mixture is also used for the piers, spandrel and retaining walls and the facing of abutments.

ARCH RING CONSTRUCTION.—Preparatory



VIEW OF REINFORCED CONCRETE BRIDGE AT GRAND RAPIDS, MICH.
L. W. Anderson, City Engineer; Joseph P. Rusche, Contractor, Grand Rapids, Mich.

*City Engineer's Office, Grand Rapids, Mich.

to the construction of the arch rings, eight spans of an old steel bridge had to be removed, cleaned and painted, and a foot bridge had to be built. Work was begun at the east end of the bridge, and as fast as the old steel spans were removed the piling for the centering was driven. Owing to the hardpan bottom these piles would not penetrate more than 6 ins. in any plane. This made it necessary to brace the piles very thoroughly, as shown by the drawings of the centers given in Fig. 3. These drawings give all dimensions, and explain the construction of the centers clearly. It will be noted that wedges formed the means provided for lowering the centering.

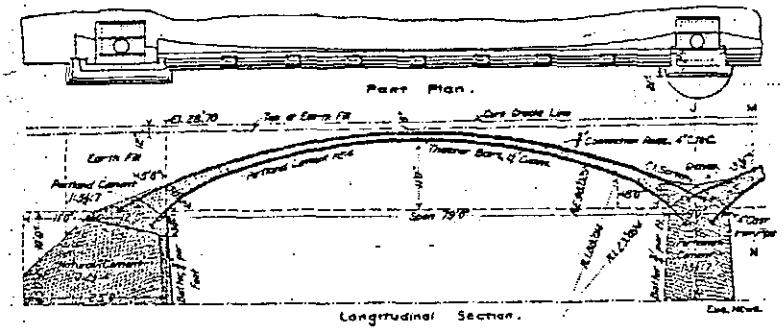


FIG. 1. PART LONGITUDINAL SECTION OF REINFORCED CONCRETE ARCH BRIDGE AT GRAND RAPIDS, MICH.

The dimensions and thickness of the arch rings for the 83-ft. spans are shown by Fig. 3, and Figs. 1 and 2 show details of one of the 73-ft. spans. The concrete used for the arch rings was composed of 1 part Portland cement, 2 parts sand and 4 parts gravel. Each ring was reinforced by 1¼-in. Thacher rods in pairs, consisting of an intradosal and an extradosal rod each. The outside pair of rods on each side of the ring is placed 3 ins. in from the face of the arch, and all the other pairs are spaced 14 ins. apart transversely of the bridge. The rods are also embedded 3 ins. in from the extradosal and intradosal faces of the ring. At the abutment and pier ends the reinforcing rods are fitted with 3-in. washers and nuts, to give them anchorage, and they are made continuous from end to end of the span by means of turnbuckles. Generally the rods came in lengths of 27 and 33 ft. Connection through the arch ring between the upper and lower rod of each pair was made every 4 ft. by means of a ⅝-in. rod, provided with a hook at each end.

The method of constructing the arch rings was as follows: The endmost sections of the reinforcing bars, which had been anchored into the piers and abutments during their construction, were bent down to the curve of the arch ring and connected up with the arch rods proper, as shown by the view Fig. 4. Scantling placed transversely across the lagging of the centers served to block up the soffit rods, while the upper rods were held in place by the connecting rods with eye hooks previously described. No trouble whatever was experienced in placing the rods and keeping them accurately in position. The concrete was mixed fairly wet, and was worked around and underneath the rods with 1x5-in. tampers in much the same way as ballast is worked under railway ties. After embedding the lower bars, a stiffer concrete was deposited and rammed in 6-in. layers. The arch ring was built in transverse sections, and each section was completed in a continuous operation in one day. The crown section was built first, and then the two skewback sections, and last the intermediate sections. To define the sections during construction a form normal to the soffit was employed. It required five days to construct each arch ring. The first arch was begun May 25, 1904, and the last was completed on Aug. 4, 1904.

SPANDREL WALL CONSTRUCTION.—The construction of the spandrel walls calls for brief mention only. The first operation was to prepare the arch ring for the wall by chipping holes into the top surface. Fig. 3 shows the construction of the spandrel wall forms, and the method of bracing them from the centers. The lagging for forming the faces of the walls was well chalked and oiled. Expansion joints in the spandrel walls were formed by simply laying the concrete against a vertical form, and then butting the following section against this smooth surface with a sheet of tar paper inserted between. The lower part of the spandrel walls inside and the whole top surface of the arch ring were waterproofed by a mortar coat composed of 1 part Portland cement, ½ part thoroughly slacked lime and 3 parts sand.

RAILINGS AND ORNAMENTAL WORK.—The railings and ornamental parts of the bridge, such as keystones, brackets, consoles, dentiles and panels, were cast in molds and set in place much as cut stone would be. Special molds were employed for each of these different shapes. These molds were plastered with an earth damp mortar composed of 1 part cement and 2½ parts fine sharp sand, which was followed up with a backing of wet concrete composed of 1 part cement, 2 parts sand and 3 parts broken stone passing a ¾-in. ring. The facing mortar was made 1¼ ins. thick. The castings cannot be told from dressed stone at a few feet distance.

The part elevation and sections in the drawings of Fig. 5 show the arrangement of the various castings to form the completed railing, coping, etc. To specify, A is the arch ring, B the brackets, C the coping, and D, E and F, respectively, the base, balusters and rail of the bridge railing. The blocks G and H show the keystone and railing post. The forms or molds for each of these parts are shown by the other drawings of Fig. 5. A description of each of these forms follows:

The keystones were molded in wooden forms, consisting of one piece, a, forming the top and front; of two side pieces, f; of a bottom consisting of two parts, b and c, and of a back piece, g.

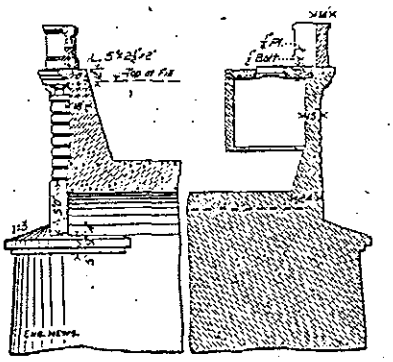


Fig. 2. Cross-Sections of Grand Rapids Bridge.

The back and side pieces are stiffened with 2x3½ in. pieces, and the front, sides and back are held together by yokes or clamps. The front of the mold was the only portion calling for particular work, and this was made of boards laminated together.

The bracket molds consisted of two side pieces provided with grooves for receiving the front and back pieces, and with slats for tie rods clamping the whole mold together. It will be noted also that the side pieces had nailed to them inside a beveled strip to form a groove in each side of the cast block. The purpose of this groove was to provide a bond to hold the bracket more firmly in the adjoining concrete of the wall. The bottom of the mold was formed by a 2-in. plank, and when the concrete had been tamped in place the forms were removed, and the bracket was left on the bottom to set. It may be noted here that a goodly number of the brackets showed a crack at the joint marked x caused by tamping at the point y. In construction the bracket castings were set at proper intervals on the spandrel walls.

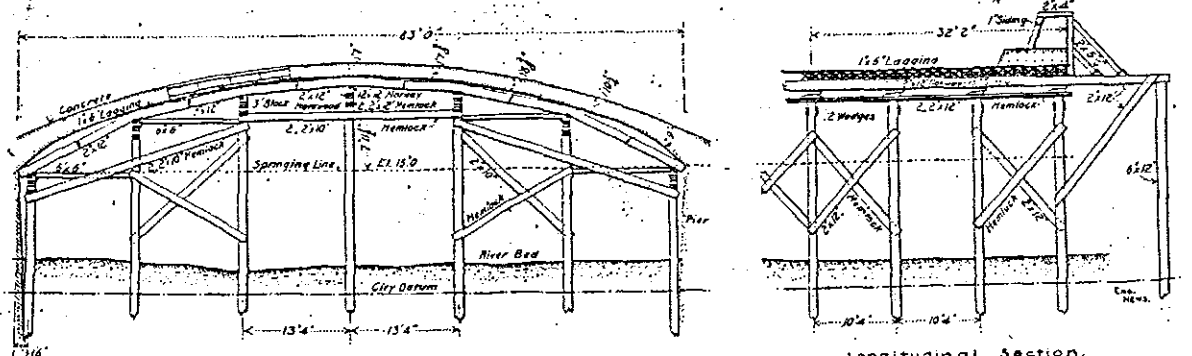


FIG. 3. CENTER FOR 83-FT. SPAN, GRAND RAPIDS BRIDGE.

which had been completed up to the level of the line X Y. The coping course was then built up around the bracket blocks to the level of the bottom of the railing base.

The mold or form for the coping course was designed to build the coping in successive sections, for the reason that the piles settled when the load was put on, which would not have occurred if the piles had received a few more blows. It took three days to chip out the same with a good force of men. Don't be too slack with tamping. Be certain that your forms are well braced, and

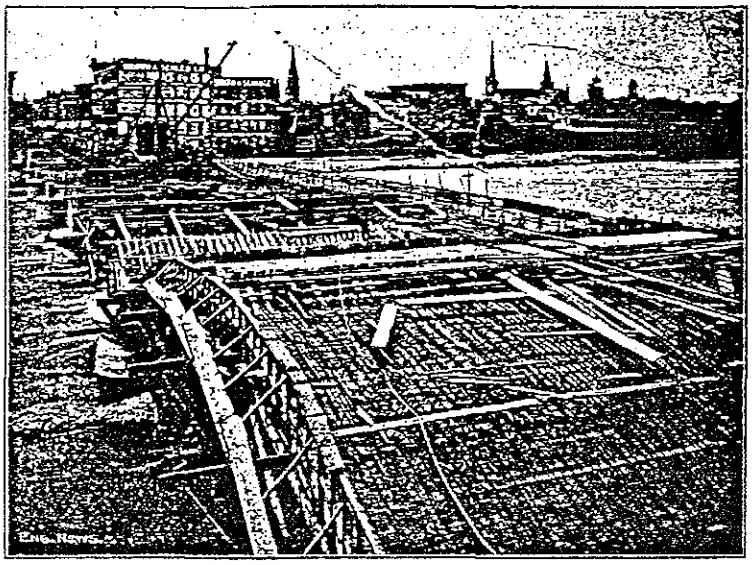


FIG. 4. VIEW OF GRAND RAPIDS BRIDGE DURING CONSTRUCTION, SHOWING REINFORCEMENT IN PLACE ON CENTERS.

and was built up around the bracket blocks, and supported from the centres as shown by the drawings. To form the expansion joints in the coping course there were inserted across the mold at proper intervals a short iron plate ¼ in. thick, cut to fit. The cutting of this plate was found to be a slow operation.

The forms for the base of the railing (section D) consisted of 1¾-in. stock for the sides, and ¾-in. stock for the slopes. They extended across the arch, and were held together by a very simple though very efficient clamp. This consisted of two 2x3x33-in. pieces nailed to a 2x3x17-in. piece by means of galvanized iron strips. About halfway down the long pieces, a ½-in. rod was run through, and secured up against blocks, h, placed about 56 ins. apart. These blocks were removed as the concrete was put in place. It will be noticed from the cross-section of the railing that the balusters are set into sockets formed in the top of the base course. These sockets were formed by means of the mold shown at W and Z.

In casting the balusters, Section (E), a ⅝-in. cast iron mold, consisting of four iron sides and an iron top, was used. Originally there were two end plates of iron, but it was found more convenient to have the bottom one of wood and allow the cast spindel to stand and set. The mold was held together by ½-in. bolts. It would have been more practical to have had the side casting composed of two parts.

The form for the railing is built up around the tops of the spindels. The bottom piece is 1x9 ins., to which 4½-in. ogee molding is nailed. The sides are of 1-in. stock, and are clamped together. The top is finished off with a trowel.

The mold for the posts is made in four parts, which fit together at the top and bottom by a bevel joint, as shown in the one-fourth section. The broad sides rest against the narrow ones, and are held against the same by means of ½-in. rods running through 2x3 in. stock; 2-in. projections of the broad sides facilitate the removal of the form from the completed post.

As regards future work of the character described here the following suggestions may be made:

Be sure you have driven your piles deep enough to be certain they will not settle. A half section of the arch ring had to be chipped out by hand thus insure yourself against any bulging. Aim to get as good a carpenter as you can for your special work.

AN INTERESTING STEEL ARCH BRIDGE DESIGN.

The great masonry dam, now nearly completed, forming the closure of the New Croton Reservoir of the water-supply of New York City will contain, as an accessory structure, a large steel arch bridge of interesting design. Bids for the construction of this bridge have already been called for, and it is expected to have the bridge completed by March 1, 1905. From the contract drawings on which bids are asked we select some representative plans and details, reproduced herewith. These show the intended construction completely; the following explanatory information, drawn from drawings and specifications, may facilitate the comprehension of the design:

GENERAL CONSTRUCTION.—The view, Fig. 1, is a front elevation of the New Croton Dam, looking upstream, i. e., toward the east. The spillway, at the left or northerly end, is a masonry overfall weir about 1,000 ft. long, curved upstream to an L-shape in ground plan and discharging into a sloping rock channel leading past the main part of the dam to the valley below. The driveway running along the top of this dam is to be carried over this spillway channel by the arch bridge in question, a structure 200 ft. in span. At one time a stone masonry arch was contemplated for this crossing, occupying the same position as shown in Fig. 1 for the steel arch. The general dimensions of the steel arch design, as rise, span and width, were fixed by the provision which had been made for the stone arch. The bridge (see also Fig. 2) is 200 ft. in span c. to c. of bed-plates, has a rise of 43 ft. 5¾ ins. from center of bed-plates to center of rib at crown, and is 18 ft. 6 ins. wide c. to c. of ribs. The total rise from water table to roadway is 58 ft.

The arch is of the unbraced or solid-rib type, as appears from Fig. 3. The two ribs are of box-girder section, with a depth varying from a maximum of 42 ins. at the crown to 36 ins. at the abutments. The ribs rest against the skewback masonry by riveted shoes bolted rigidly to the masonry; they are therefore fixed-end arches. At the crown, however, a 10-in. joint-pin is provided. In addition the ribs are spliced by riveted connections at the crown. The following clause in the specification, which does not necessarily refer to arch ribs, may indicate the reasons for the compound pin-and-riveted crown joint:

> All field joints and connections shall be thoroughly riveted up at such a stage of erection that all members are truly lined up and free from internal strains and twists when swinging the bridge free.

As the bedplates of the ribs are cast solid with cement mortar, after the ribs have been connected up, there are thus virtually three hinges during erection, which will ensure the absence of initial stresses.

The two arch ribs are set in vertical planes. They are braced together by a full system of four-angle lattice struts and crossed four-angle diagonals. The panel-points of this lateral system correspond with the roadway posts.

The roadway is a horizontal plate composed of transverse 15-in. I-beams spaced 4 ft. 6 ins. apart,

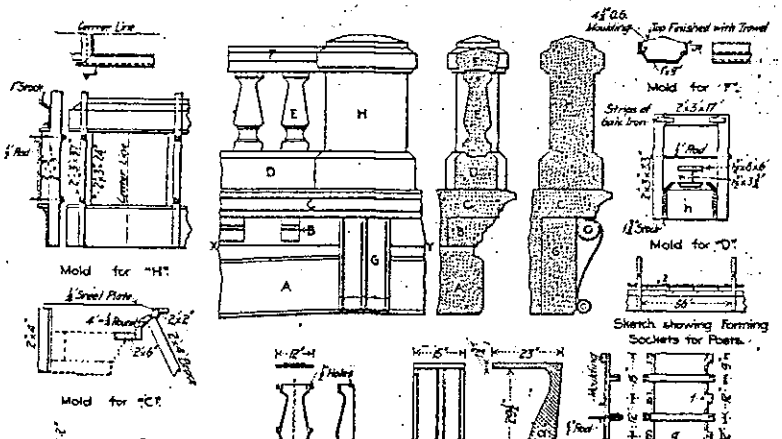


FIG. 5. DETAILS OF SPECIAL FORMS FOR RAILINGS AND ORNAMENTAL PARTS.

and concrete arches turned between these beams. The beams themselves are supported by two longitudinal arcades of riveted construction, continuing downward in the form of built-up steel posts to a footing on the arch-rib. The posts are of box section and the arches connecting their